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Salt Glazed Clay Surfaces

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SALT GLAZED CLAY SURFACES

BY

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The topic of my thesis work is Salt Glazed Clay Surfaces. I had no idea at the outset that the study of this area of ceramics, for me, would be such an involved experience. In addition to an exploration of possible surface embellishments appropriate to salt glazed ware, much study was given to kiln construction and firing techniques, use of coloring agents, and clay body formulation. Because of the many inconsistencies from one firing to the next, it is difficult, if not impossible, to duplicate specific results or to previsualize certain effects in finished pieces. For this same reason, it is almost as difficult to come to absolute conclusions about the methods tested or the techniques employed. Accordingly, much of my research was conducted with the intent being to understand salt glazing and not to ultimately control it.

My hope is that this paper will, in addition to being a report of my thesis work, save other potters the time and expense of trial and error experimentation and poor choices of materials.

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INTRODUCTION

Salt glazing of ceramic ware is not a new process. Its use dates back to 12th century Germany. In America, salt glazing predominated as the usual method employed by most stoneware potters until the 1880's when the Bristol glaze was introduced. Within the past few years, however, salt glazing has enjoyed renewed popularity as a technique employed by many potters.

Salt glazed ware is economical to produce. The pieces need only be once fired and are rendered waterproof without the use of applied glazes.[1] Industry has made much use of the technique in the production of chemical stoneware and building materials such as tiles, bricks and conduits. Sewer pipes are a good example of a salt glazed product which is durable, waterproof, and resistant to chemical attack.

The method of salt glazing is a simple process. the ware is heated to a temperature where vitrification of the clay begins, at which point salt (sodium cloride)

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[1] An exception to this would be closed forms and covered jars which are usually lined with a slip or glaze due to the salt having no effect on enclosed surfaces.

is introduced into the kiln. The salt volatilizes forming fumes of sodium oxide which combine with the free silica in the clay forming a sodium silicate. This in turn combines with the clay substance, thus forming a sodium aluminum silicate glaze on the surface of the ware. The by-product of this process is chlorine gas which combines with hydrogen to form hydrochloric acid. In addition to forming a glaze on the ceramic ware, the sodium fumes also attack the shelves, kiln furniture, and the inner kiln wall. This necessitates a kiln especially suited to salt glazing.

The salt glaze is quite unique, usually having a glossy surface interrupted, to varying degrees, by numerous small pits or craters. The resulting glaze texture resembles the "pig skin" of a football or the surface of an "orange peel."

KILN DESIGN AND CONSTRUCTION

Before any salt glazing could be initiated at R.I.T., a kiln dedicated to this process had to be constructed. Soft insulation brick could not be used since the corrosive sodium vapors would disintegrate the lining in the first firing. A hard fire brick lining is much more resistant to the sodium vapors and is, therefore, a necessary choice. With successive firings, however, the hard brick will season (take on a salt glaze) and eventually disintegrate whereupon the kiln will, in effect, self-destruct. With proper materials and construction techniques, a salt kiln should last in excess of 100 firings.

The most common kiln design used for small (100 cubic feet or less) salt kilns is a down draft style. This design insures more complete circulation of the sodium fumes throughout all parts of the kiln.

It was decided to construct the kiln from materials already on hand. A catenary arch design was chosen since most of the available hard bricks were of the wedge and arch variety. A castable refractory made from crushed insulation bricks with Portland cement and fireclay as a binder would serve as a second or insulating layer, and a weather proofing shell could

be constructed from the seemingly endless number of common bricks leftover from the construction of the new campus.

After estimating an internal size of about 40 cubic feet based on the number of available brick, the stacking area was established at 2'x 4'. Using the principle of designing a kiln from the inside out, the total floor area came to 45"x 52" (see figure 1, floor plan). This included 6" wide fire boxes, 2½" bag walls and a 2" circulation space around the stacking area. The internal height of the kiln was chosen to equal the width of 45". Allowing for the thickness of the hard brick wall, castable refractory and common brick shell, the outside dimensions came to 78"x 72½".

The construction began with the laying out of a concrete block subfloor upon which two layers of 3" thick x 9"x 14" floor tiles were placed and mortared. The mortar used throughout the construction was: 2 parts Portland cement, 2 parts fireclay, and 1 part grog or sand.

To build the arch, a form constructed of plywood, 2 x 2's, and masonite was used (figure 2). The curve of the arch was established by hanging a chain from two nails placed 45" apart (the width of the kiln). The length of the chain between the two

nails was adjusted until the bottom of the curve it defined fell 45" (the height) below the line drawn between the two nails. The curve of the chain was then traced onto two plywood sheets which were cut out to become the end walls of the arch form. The completed form was placed on the kiln floor and construction of the arch began, first using the wedge bricks until their supply was exhausted and then resorting to arch bricks to complete the job (figure 3). Space for two burner ports 4½" x 4½" was allowed at the base of each side of the arch. The back wall was then built up underneath the arch thus giving it added support and serving as a partial heat lock. An 8½" x 8½" opening was allowed in the bottom of the back wall for the flue.

An insulating layer of a castable refractory was now applied over the entire hard brick lining. The recipe for the castable used is 1 part cement, 1 part fireclay, 2 parts crushed insulation brick and 1 part sawdust or woodchips. Since the castable had a tendency to sag before it set, especially on the vertical sections, the outer common brick shell was constructed at the same time the castable was applied, that is, a foot of castable, a foot of common brick, a foot of castable, and so on. (See figure 5.) As an additional insulation, as-

bestos planks were used on the crown of the kiln between the castable and the common brick outer shell. (See figure 7.) The asbestos being soft and somewhat spongy, would also serve to absorb the expansion of the inner layers of the kiln which would occur during firing. This would hopefully eliminate extensive cracking of the outer shell.

The two front wall sections were now built thus completing the major construction of the basic kiln. Two "salting ports" were left in the wall sections, one on each side of the door opening, each being located at about 20" above the kiln floor.

The stack, standing about 15' high with a cross section of 18" x 18", was constructed of common brick. The unusually large dimensions of the stack are explained by the fact that ultimately three kilns would be tied into it, possibly all firing simultaneously. A horizontal flue connecting the kiln to the stack was built out of hard fire brick leaving a slot wide enough for the damper (an old kiln shelf was used) about midway in its length.

The door to the kiln is simply an unmortared wall of bricks: three bricks wide (27") and two bricks thick (9"). The door is made of hard fire brick on its inner layer and insulation brick on its outer

face. Lastly the bag walls were laid in place thus defining the fire boxes. (See figure 1, front cross section.)

A protective wash of 65% alumina oxide and 35% kaolin was applied to the floor, bag walls and fire boxes to prolong the life of these areas most subjected to the sodium fumes. The inner surface of the door was also washed so as to keep the bricks from being glazed together.

Four forced air burners from an old Alpine updraft were modified for use on the salt kiln. The original blowers did not deliver sufficient air to produce an oxidation flame and were therefore eventually replaced with a system of air pipes connecting the burners to a large Denver Fireclay blower (figure 8). With this air system it was quite easy to maintain an oxidation atmosphere in the kiln yet reduction could be produced by simply cutting back on the air supply from the blower. The firing and salting procedures will be discussed later.

It is important to mention, at this point, the effect of a number of firings on the kiln materials used. Three types of hard brick were used, A. P. Green Valentine XX bricks, Harbison-Walker Temple bricks, and Harbison-Walker Woodland X bricks. The Valentine XX

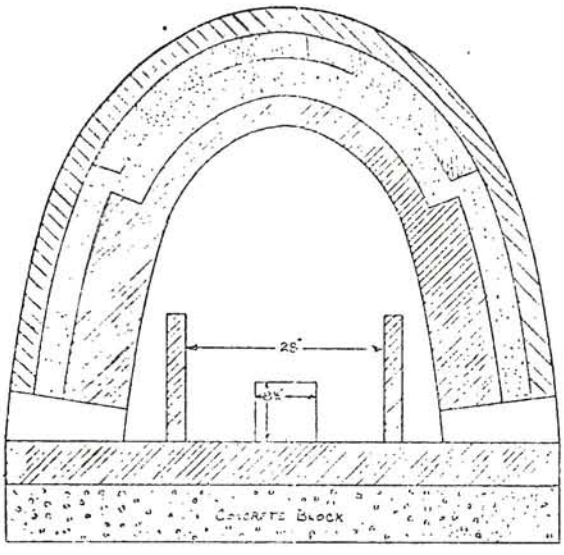
and Temple bricks were given to the school by the Syracuse China Corporation. The Temple bricks, appearing to be less porous and harder than the Valentine XX bricks, were used around the burner ports and in the bag walls. The Valentine XX bricks made up all of the arch except for two rows of Woodland X bricks.

After the first few firings the Temple bricks showed much deterioration in the form of sagging, foaming and breaking apart. The Valentine XX bricks held their shape rather well, but were very heavily glazed and showed separation between the joints. This is partly explained in that the mortar melted and ran out from between the bricks. A call to the local brick representative provided the explanation for this rapid deterioration. The Temple bricks are the lowest duty variety in the Harbison-Walker product line and were not designed to withstand the temperatures and atmosphere found in the salt kiln. The Valentine XX is a "semi-silica" brick which is produced for use in blast furnaces and open hearths. The high silica content gives the brick a substantial refractory quality, but at the same time makes for heavy glazing and deterioration of the exposed surface in the salt kiln. The Woodland X bricks have held up

very well to this point (ten firings). They have maintained their original shape and show minimal glaze build up.

As a hindsight consideration of the selection of materials, I would suggest using a high duty or super duty brick throughout the kiln cemented together with a high alumina mortar. The salt kilns at Alfred University are constructed with Harbison-Walker Woodland X bricks. Don Reitz uses A. P. Green Clipper bricks and recomends A. P. Green Satanite or Grefco's Arco 70 as mortars. At an additional expense high alumina bricks could also be used, especially in the fire boxes and around the burner ports.

Appendix A contains a listing of fire bricks tested in the salt kiln for their resistance to salt glazing



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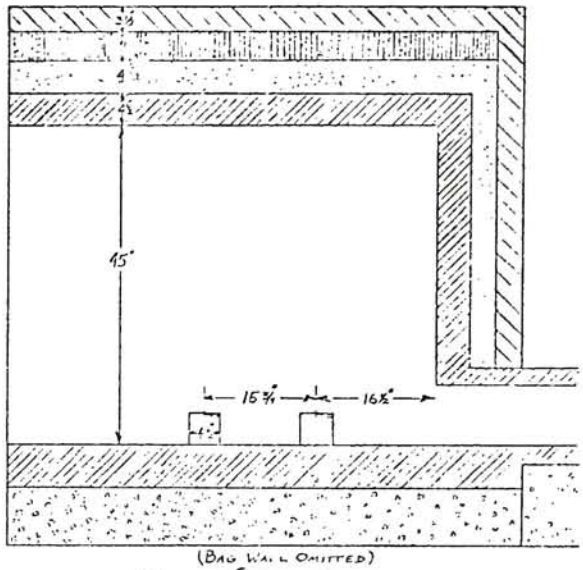

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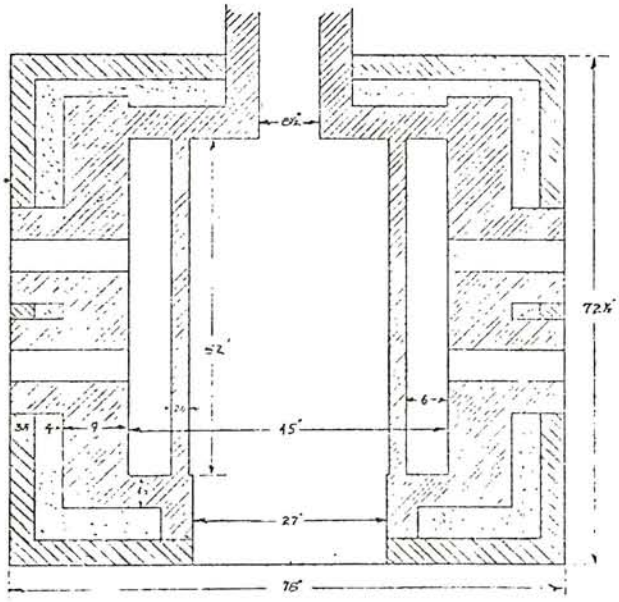

FLOOR PLAN

CATENARY ARCH
SALT KILN

SCALE: 1" = 27"

Common Brick

Castable Refractory

Hard Fire Brick

Asbestos

Figure 1. Salt kiln plan.

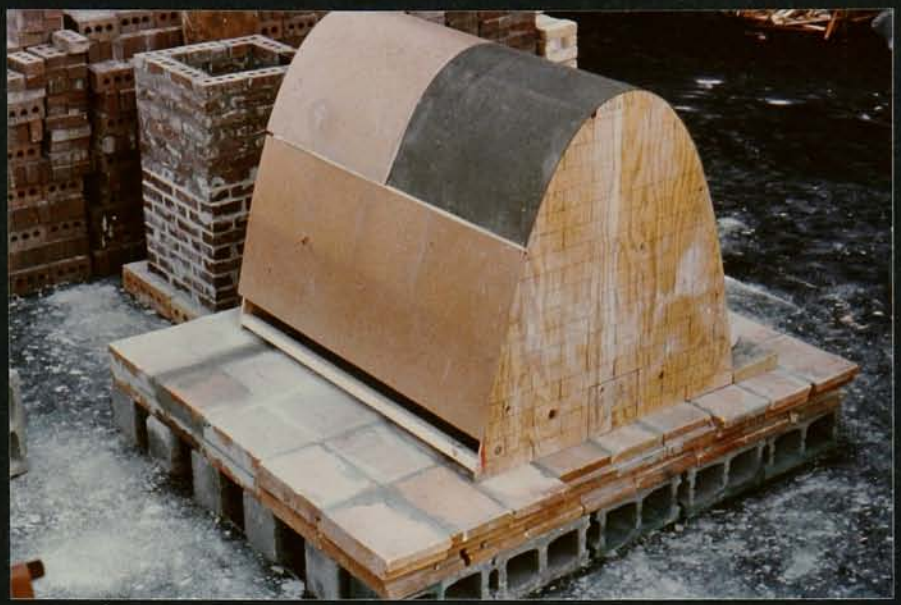

Figure 2. Kiln floor with arch form.

Figure 3. Hard brick arch and burner ports. Note the use of wedge and arch bricks.

Figure 4. Hard brick arch with form removed.

Figure 5. Detail of castable refractory and shell construction.

Figure 6. Hard brick arch with castable refractory cap. Bricks temporarily stacked for door.

Figure 7. Detail of asbestos planks between castable refractory and common brick shell.

Figure 8. Modified Alpine forced air burners.

Figure 9. The completed salt kiln.

FIRING AND SALTING PROCEDURES

An oxidizing atmosphere is maintained in the kiln fron the beginning of the firing cycle until cone 9 is flat. During this time the damper is kept wide open. At cone 9, the damper is closed until there is back pressure producing a flame of about 6" at the front spy holes and salting ports. This is done to insure a thorough saturation of the atmosphere with sodium vapors. In addition, the reduction and fire flashing that occurs when the damper is closed converts the ferric iron to the ferrous state in which condition the clay will take a better glaze. At this point the salt is introduced into the kiln, preferably in small quantities. I use about ten pounds per salting. One of the salting techniques I have used is to toss scoops full of salt in front of the burners through the burner ports. This system works relatively well as long as you have a good aim and do not spill too much salt. Another salting method is to fill a long section of angle iron with salt, insert in through one of the front salting ports and rotate it in the direction of the fire box so that the salt falls into the flames. This system is very efficient in that there is little spillage or

loss of salt, but it requires two people to complete the salting, one to hold the angle iron and the other to fill it with salt.

Periodically, during each salting, the damper is rapidly pushed in and pulled out a number of times to pull the atmosphere, in jerking movements, to all parts of the kiln. This also insures that the sides of the pieces facing away from the fire boxes are well glazed. At the end of the salting, the damper is opened and the kiln atmosphere is allowed to clear (usually about five minutes). One of the draw rings which have been placed near a spy hole in the door is pulled to examine the glaze buildup after each salting. The ring should have a broad enough surface to adequatly show the glaze buildup and it should be made of the same clay as is used in the majority of the pieces in the kiln. A small ring shape is usually chosen so that it can easily be hooked with a rod and pulled out through the spy hole. The color of the ring is not a good indication of the color of the finished ware. The extremely quick cool, usually quenching it in water, gives the ring a very light color.

The saltings continue until the glaze on the draw rings is of the desired thickness. After the

last salting, the firing is allowed to continue for another fifteen minutes or so to allow the kiln atmosphere to clear as much as possible. The burners are turned off, the damper is closed and the burner ports are bricked up to prevent cold air from being drawn into the kiln, possibly causing dunting and mat surfaces on the pieces near the fire boxes.

I find that a rapid cool of the kiln produces brighter colors, particularly in slip decorated ware, a shinier surface, and a more pronounced orange peel effect. The fast cool also keeps the clay from turning brown which would occur through the reoxidation of the iron on the surface from the ferrous to the ferric state. The rapid cool is accomplished by removing the top few courses of brick from the door which allows the heat to escape in updraft fashion. Just prior to the loss of red heat, the kiln door is bricked up again to slow the cooling through the quartz inversion temperatures.

CLAYS AND CLAY BODY FORMULATION

There are three main factors that effect the amount of salt glaze that will form on a clay: the amount of salt introduced into the kiln, the amount of free silica present in the clay, and the degree of vitrification of the clay at the time of salting.

Throughout all of my firings, I have tried to keep the glaze thickness, due to the amount of salt used, constant. Less salt needed to be used with each successive firing because of increased seasoning[3] of the kiln. Even with this attempted control, certain areas of the kiln would produce more heavily glazed pieces than others. This may be due to a heavier concentration of sodium vapors in these areas.

Free silica is necessary in a clay for the formation of a salt glaze. Clays do not occur naturally in the form of oxides, as might be concluded from studying a chemical analysis, but are made up of various mineral constituants including clay substance or kaolinite ($Al_2O_3 \cdot 2Si_2O_3$), feldspar ($KNaO \cdot Al_2O_3 \cdot 6SiO_2$), and quartz or free silica (SiO_2). Free silica is, therefore,

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[3]With each firing, the glaze buildup on the kiln wall increases and therefore absorbs less of the sodium vapors. The effectiveness of the salt is increased with each firing, therefore less is needed.

that silica which occurs in a clay in excess of the combined silica of the clay substance and of the feldspar. The amount of free silica in any given clay can be determined from its chemical analysis by various methods, including a conversion to "rational analysis" which expresses the clay in terms of its mineral components.

Another and much simpler way of relating the silica content of a clay to its ability to take a salt glaze is by determining the ratio of its alumina molecules to its silica molecules (Al_2O_3/SiO_2). From its chemical analysis, this is easily done by dividing the alumina content into the silica content and reduing the results to a molecular ratio. An example follows for E.P.K. The alumina and silica content is taken from Table 1.

(a) $$\frac{45.91\ (\%\ SiO_2)}{38.71\ (\%\ Al_2O_3)} = \frac{1.185}{1} \quad \text{or} \quad 1 : 1.185$$

(b) Reduce to molecular ratio.

$1 \div 102$ (Mol.Wt. of Al_2O_3) : $1.185 \div 60$ (Mol.Wt. of SiO_2)

$.0098 : .0197$

$1 : 2$ (Al_2O_3/SiO_2 of E.P.K.)

A simple equation quickly renders the same results.

$$Al_2O_3/SiO_2 = 1 : (\%\ SiO_2 \div \%\ Al_2O_3) \times 1.7$$

Therefore E.P.K.'s Al_2O_3/SiO_2 could be calculated as follows:

$$Al_2O_3/SiO_2 \text{ (E.P.K.)} = 1 : (45.91 \div 38.71) \times 1.7$$
$$1 : 1.185 \times 1.7$$
$$1 : 2$$

The following tables show the chemical analyses and the Al_2O_3/SiO_2 of the clays tested.

TABLE 1

CHEMICAL ANALYSIS OF CLAYS TESTED

Clay	SiO_2	Al_2O_3	Fe_2O_3	KNaO	TiO	CaO	MgO	L.O.I.
E.P.K.	45.9	38.71	.42	.26	.34	.09	.12	14.15
A.P.G. Mo. Fire Clay	56.5	38.5	1.8	1.0	1.5	.5	.3	
Tenn. #5 Ball Clay	51.79	31.31	1.01	2.31	1.41	.26	.20	11.70
Ky. Special Ball Clay	49.64	29.33	.95	1.25	1.48	.29	.25	16.8
XX Sagger	56.68	29.19	.72	1.20	1.65	.45	.32	9.9
C.H. Goldart	57.32	28.50	1.23	1.18	1.98	.08	.22	9.39
Jordan	67.19	20.23	1.73	2.23	1.18	.16	.52	8.89

TABLE 2

Al_2O_3/SiO_2 OF CLAYS TESTED

Clay	% SiO_2	% Al_2O_3	Al_2O_3/SiO_2
E.P.K.	45.91	38.71	1:2
A.P.G. Mo. Fire Clay	56.5	38.5	1:2.5
Tenn. #5 Ball Clay	51.79	31.31	1:2.8
Ky Special Ball Clay	49.64	29.33	1:2.9
XX Sagger	56.68	29.19	1:3.3
C.H. Goldart	57.32	28.50	1:3.4
Jordan	67.19	20.23	1:5.6

All of the above clays were made into test bars and fired in the salt kiln. To insure an adequate sample for evaluation, a number of bars were made from each clay and at least two were placed in each of three different firings.

The results of the clay tests follows. The clays are listed in order of increasing thickness of salt glaze. Al_2O_3/SiO_2 of the clays are included.

E.P.K.-(1:2.0) Light in color with orange flashes on most of the exposed surfaces. No glaze formation.

This is mostly due to no free silica present in the clay.

A.P.G. Missouri Fire Clay-(1:2.5) Dark brown with a rough texture, possibly due to the large partical size of the clay. Thinly glazed surface with much strong pitting.

Tennessee #5 Ball Clay-(1:2.8) The lightest color of the ball clays tested. Light tan to cream color with a finely textured surface.

Kentucky Special Ball Clay-(1:2.9) Warm tan to light brown with a smoothly glazed surface, smoothest of all of the clays tested.

XX Sagger-(1:3.3) Rich warm yellow color with orange flashes. Delicate orange peel texture on a fairly thick glaze.

Cedar Hights Goldart-(1:3.4) Light brown to tan to warm grey. Thick, textured glazed surface that could be called the typical "orange peel" effect.

Jordan-(1:5.6) Cool brown to light grey in color with a fine orange peel texture. The thickest glaze of all clays tested.

It is important to note the direct relationship between the glaze thickness and the Al_2O_3/SiO_2 of the clays. E.P.K., with no glaze, has a ratio of 1:2 and Jordan, with the thickest glaze, has a ratio of 1:5.6.

Another factor which effects glaze build up on a clay is its degree of vitrification at the time of salting. At cone nine, E.P.K. is the least vitreous of the clays tested, its absorption being 13%. Jordan's absorption at cone nine is about 1.5% making it the most vitreous.

To confirm the above relationships, a series of tests were developed. E.P.K. was chosen as one of the base clays for the tests because it is not vitreous at cone nine, has no free silica, and does not take a salt glaze. The first series included additions of silica to E.P.K. increasing its Al_2O_3/SiO_2 from 1:2 to 1:11. A second series of tests with feldspar additions was performed to study the effect of fluxing the clay. A third test series was made with additions of Plastic Vitrox. Plastic Vitrox was chosen since, from its empirical formula, it resembles a feldspar yet has more than twice as much silica.

Theoretical Feldspar:

$$1RO \cdot Al_2O_3 \cdot 6SiO_2$$

Plastic Vitrox:

$$1RO \cdot 1.69Al_2O_3 \cdot 14.67SiO_2$$

Similar additions were made to A.P.G. Missouri Fire Clay (A.P.G.), to observe the effect on the color of the dark clay, and to a basic stoneware Test Body. The test body was formulated to have good working qualities, light color, and an ability to take an "orange peel" type salt glaze. Cedar Hights Goldart was chosen for its general working characteristics and orange peel glaze, A.P.G. to add tooth and to open up the body, and Tennesee #5 Ball Clay for its light color and plasticity.

Test Body

C.H. Goldart	50
A.P.G.	20
Tennesee #5 Ball	25
Grog	5
	100

The tests were made into small bars and fired in the salt kiln. To measure vitrification, duplicate tests were fired in a regular stoneware kiln to cone 10-11[4] and their percentage of absorption was calculated. The results of these absorption tests can be found in

[4]These tests were intended to be fired to cone 9, but overfired. Regardless, the trends which can be seen in the results of the tests are what is important.

Appendix B.

In every case, the additions of flint to the clays improved their ability to take a glaze. The E.P.K. series, with flint additions, dramatically illustrates the effect of the increased silica on the glaze and the color of the clay. With no flint addition, the E.P.K. tile has a smooth but dry surface with no glaze formation. As flint is added, up to 20 parts to 100 parts of E.P.K., the orange color of the exposed surfaces lightens to a creamy tan, and some glaze formation is evident. With 25 parts flint, the Al_2O_3/SiO_2 is increased to 1:3.1, the glaze buildup is good, and the tile is a creamy white with only slight orange flashes. Increasing additions of flint continue to whiten the clay and improve the glaze thickness. At 200 parts flint to 100 parts E.P.K., the tile is a clean, bright white color with a delicate orange peel type glaze.

The A.P.G. tests with flint additions produced similar results to the E.P.K. series. With increasing additions of flint to 100 parts of A.P.G., the Al_2O_3/SiO_2 is increased to 1:3.0 and a good glaze formation occurs.

The Test Body, with an Al_2O_3/SiO_2 of 1:3.0 takes a fairly good glaze which is improved with the addition

of flint. As in the above tests, the color gets lighter with increased flint. In both the Test Body and A.P.G. test series, the pitting or orange peel effect becomes stronger with the flint additions until the absorption of the test tiles exceeds 7%. At this point, the glaze surface begins to smooth out and the pitting becomes delicate and less pronounced.

Custer Feldspar was chosen for the feldspar additions to the test series. It has slightly more silica than the theoretical feldspar.

Theoretical Feldspar:

$$1RO \cdot Al_2O_3 \cdot 6SiO_2$$

Custer Feldspar:

$$1KNaO \cdot 1.05Al_2O_3 \cdot 7.05SiO_2$$

In each of the series, the feldspar additions increase the vitrification of the clay and, like the flint, lighten the color. The feldspar additions to E.P.K. did little to affect its ability to take a glaze. With the larger feldspar additions, a very thin glaze forms which is probably due, in part, to the introduction of some free silica with the feldspar.

A.P.G. shows an improvement in glaze thickness with the initial feldspar additions. Additions in excess of 20 parts per 100 parts of A.P.G. seem to have no effect other than to lighten the color.

The Test Body is effected similarly by the feldspar. The initial addition of 3 parts feldspar to the body reduces the absorption by almost one half and produces a marked improvement in the glaze thickness. Subsequent additions of feldspar increase the vitrification only slightly and the glaze thickness shows little improvement.

As a follow up to the above tests, combined additions of feldspar and flint were made to the Test Body. With 2 parts flint and 2 parts feldspar added to 100 parts of the Test Body, the color is much lighter and the glaze thickness is greatly improved. This combined addition produces a thicker glaze than either the flint or feldspar added separately. Subsequent combined additions continue to improve the glaze slightly.

In general, the Plastic Vitrox additions did not produce results as satisfactory as those obtained by using feldspar, flint, or the two in combination. As a flux, Plastic Vitrox is not as effective, weight for weight, as the feldspar in reducing absorption and as a source of silica, Plastic Vitrox does not compare to flint. A combined addition to the Test Body of 6 parts of flint and 6 parts of feldspar produces a thicker glaze and a more vitreous clay body than does an addition of 12 parts of Plastic Vitrox.

Talc ($3MgO\ 4SiO_2\ H_2O$) and Wollastonite ($CaO\ SiO_2$) were tested for use as possible fluxes in salt bodies. In both cases, when 10 part additions were made to the test body, dry crystalline mat surfaces were produced. Spodumene ($Li_2\ Al_2O_3\ 4SiO_2$), used in 10 percent additions, produces a bright glazed surface that is subject to severe shivering.

Silica sand added to a clay body will increase the orange peel character of the glaze. Whereas finely ground (200 or 350 mesh) silica added to a clay body increases the glass forming material and accordingly improves the glaze thickness, a concentration of silica, like that found in the larger particle size of silica sand, tends to repel the salt glaze. The orange peel quality of the salt glaze on naturally occuring clays like C.H. Goldart and A.P.G. may be due, in part, to the presence of concentrations of silica.

In summary, to produce a clay body that will take a salt glaze that is bright and relatively thick, having a good orange peel texture, the following guide lines can be applied.

1. The clay body should have an Al_2O_3/SiO_2 of at at least 1:3. (Flint can be added to increase the silica.)
2. The clay body should be vitreous within the

stoneware range at the time of salting. (Feldspar additions can be made to increase vitrification.)

3. Calcia and magnesia should be avoided since they produce mat surfaces.
4. Silica sand can be added to increase the orange peel effect.

Included in Appendix C are some formulas of clay bodies which take a good glaze in the salt kiln.

COLORING OXIDES AND SLIPS

A wide variety of glaze colors can be achieved in the salt kiln. Colors may range from reds, yellows and oranges to greens, blues and black. Color responses are different from that of the high fire reduction kiln in that an oxidation atmosphere is usually sought in the salt firing.

Raw colorants can be dusted or rubbed onto dry or bisqued pieces or a wash of the colorant in water can be applied with a brush or spray gun. Additionally, a white base slip with colorant additions can be applied to wet, dry or bisqued ware. I use a slip based on a variation of the classical porcelain clay body. It consists of equal parts of Tennessee #5 ball clay, XX Sagger clay, flint and feldspar. The slip produces a smooth glazed surface which has less tendency to form an orange peel texture than does the exposed clay.

The raw colorant tends to produce colors that are stronger and appear to be more on the surface of the glazed piece than does the same colorant applied in the slip. An example of this can be seen in figure 16 where the colorant, rutile in this case, appears to be floating on the surface of the glaze.

Some of the most common colorants used on salt

glaze ware are cobalt oxide, rutile, uranium oxide and iron oxide. Rutile will produce creamy blues to straw tan colors often forming iridescent crystals. Cobalt oxide will give blues and when used with rutile will produce greens. Uranium oxide salts a yellow to warm orange and iron oxide ranges from a rich rust to brown. Varying success was achieved with the oxides of manganese and chromium, both of which produced dark browns or brown greens. Together in combination with iron oxide and cobalt oxide they produce a good black. Titania used alone will produce a rather dry, iridescent light green to creamy white. I have used it more successfully, however, in combination with other colorants in a slip form. The titania brightens the other colorants and gives them a crystalline iridescence.[2]

I did some limited testing of commercial glaze stains and found that, in most cases, they lost their color or became muddy in the salt kiln.

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[2]A more specific listing of slips and colorant additions can be found in Appendix C.

THE SALT GLAZED SURFACE

The salt glazed surface has a very unique character. It can be smooth and glossy or textured and mat, but mostly it is a bright surface broken up by many small pits, thus creating the orange peel effect.

My first few firings in the new salt kiln were somewhat disappointing for me. This was partly due to my using a clay body that did not lend itself to the development of the light colored, irregular orange peel surface that I was seeking and to the newness of the kiln and my unfamiliarity with it. Mostly, however, this disappointment was due to my making the same type of pieces for the salt kiln as I had been producing for the reduction fired stoneware kiln. I had been pleased with this type of piece with opaque, smooth mat glazes, but with the irregular salt glazed surface, they seemed weak and unconvincing. I had not given enough consideration to the nature of the salt glaze nor explored the possible forms and surface qualities which it could best enhance.

The surface of the raw clay is revealed in the salt firing. Textured surfaces are accented and every scratch is magnified. Smooth clay surfaces take on a stoney character. Because of the many inconsistancies in temperature, atmosphere, and sodium vapor penetration

throughout the salt kiln, uniform results from a firing can never be expected. An excellent example of this variation can be seen in figure 10. The clay slab was not treated with any colorants or slips. The color variation is simply the effect of fire flashing and fumes from oxides used on nearby pieces. It is important that pieces destined for the salt kiln be of a character that will be improved by the flashing, drips and uncontroled happenings that are bound to occur.

As part of rethinking the nature of my work produced for the salt kiln, I spent much time studying photographs of pottery having surface qualities that I felt might work especially well if salt glazed. The Japanese pottery, particularly of the Iga, Shigaraki, and Bizen traditions, was of interest to me because of its irregular and spontaneous surface treatment. The effect of the wood firing process on these pieces enhances them in much the same way that the salt firing reveals and accents. Both types of firing techniques have in common the effect of inconsistancies in atmosphere, temperature and fire flashing, which can blush the side of a pot. As in the salt kiln, a glaze (in this case, wood ash) naturally occurs on the pottery, forming mostly on the shoulders and broad areas of the pieces. Often, in the wood kiln, the ash is caught by a scratch

or irregularity in the clay, forming a glaze, and therefore magnifying the texture. In the salt kiln, the glaze pulls away from sharp edges, high points, or irregularities, and becomes thinner than usual, thus allowing the color of the lighter body to show through.

With these thoughts in mind, I tried to incorporate some of the surface techniques used in the Japanese pottery into my own work. At first, I attempted to duplicate the complete piece which I was studying. The results ofted looked contrived and forced. By performing this exercise however, I was able to catch a glimpse of the spirit that was put into some of the pieces by their creators. As I moved away from copying the originals, I still tried to retain their spirit in work that was more my own. I would throw a basic form and then begin to experiment with the surface; first by breaking up the regular throwing lines with my fingers or a flat edge. Then, using the sharp corner of a rib, broad horizontal lines could be created. Often one or two vertical incisions would finish the piece. The vase in figure 17 shows the use of some of the above techniques.

In all this time I had not been giving any consideration to the use of applied colorants. All of my attention had been focused on surface and form. I began to use colored slips on the pieces, usually

when they were still on the wheel. Working in this manner I felt more free to experiment with the slips, knowing that if I did not like the immediate results, I could erase the slip with a sponge or rib and start again. The most satisfying results of using the slips were achieved by applying them to relatively smooth or open areas of a piece and then working into the surface thus revealing the clay from under the slip coating. In this way, the slip seems more integrated into the clay surface.

Another technique which I use regularly is the spraying or dusting of raw oxides onto dry or bisqued pieces to create blushes of brown, gold or blue. The sprayed oxide partly inhibits the formation of the orange peel surface and causes some mattness. I feel that the results from this method are most pleasing when the oxides are used sparingly, thus producing flashes in limited areas.

The sodium vapors which produce the salt glaze are carried with the flame to the pots and as a result have little effect inside deep bowls or cylindrical forms since the flame does not travel to these areas. Accordingly, it is necessary to coat these surfaces with a glaze or slip if they are to hold liquids. Two glazes which work well for this purpose are

Voulkos Plum, a saturated iron glaze which gives a pale yellow-green to rich red-brown and Rhodes Black, a high Albany Slip glaze yielding a rich midnight blue to black depending on thickness. Q 10 Satin, an opaque white glaze, makes a good liner for covered forms. (The formulas for these glazes can be found in Appendix C.) Occasionally, I splash or drip these glazes, in small amounts, onto the outer surfaces of the pots. When used with the spraying of oxides, as mentioned above, some very interesting results are produced. See figure 16.

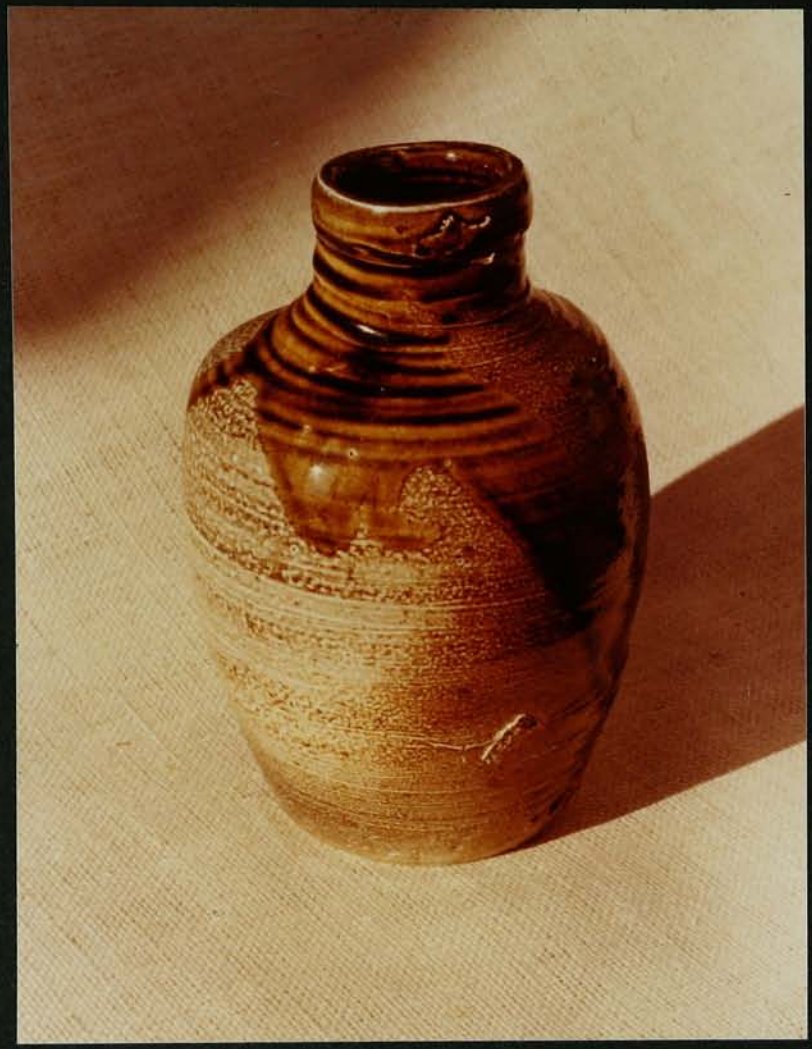
The method of stacking pieces in the kiln can also effect their color and surface quality. Pots stacked tightly together will not take as thick a glaze as those stacked loosley. Pieces can be placed lying on their side or stacked one on another, separated with wads of kaolin and alumina. Interesting glaze resist marks are produced in this manner. Pieces can be placed in the fire boxes or on the bag walls, thereby taking on rich brown colors from the fire flashing. Target bricks can be used to direct the path of the flame onto or away from a piece. Deep blue or black blushes can be achieved by placing pots near a brick or stilt painted with a wash of cobalt oxide. See figure 11b.

Other areas of surface enhancement which I was unable to explore are the addition of colorants to the salt and the development of lusters by fuming with chlorides.

With all of these possible techniques to choose from, the potter should never be at a loss for variation from his salt kiln.

Figure 10. Clay slab showing salt glaze variation.

Figure 12. Tea bowl with Voulkos Plum glaze.



Figures 11a,b. Vase with Voulkos Plum glaze dripped over the shoulder. The black blush seen in 11b is the result of fumes from Cobalt oxide painted on a nearby stilt.

Figure 13. Dorabochi (low, wide dish)

Figure 14. Vase.

Figure 15. Vase.

Figure 16. Vase. Note areas sprayed with iron oxide and rutile.

Figure 17. Vase.

Figure 18. Mug.

Figure 19. Small porcelain vase.

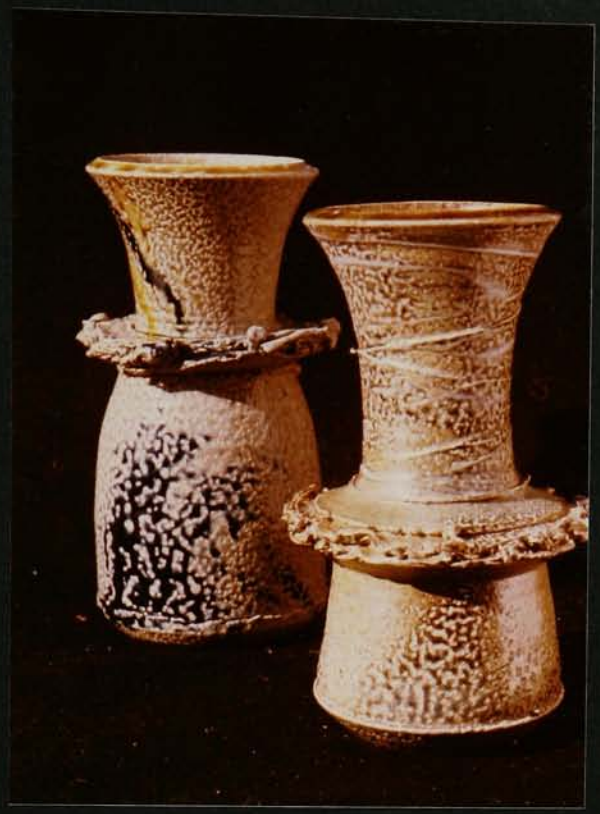


Figure 20. Pair of vases.

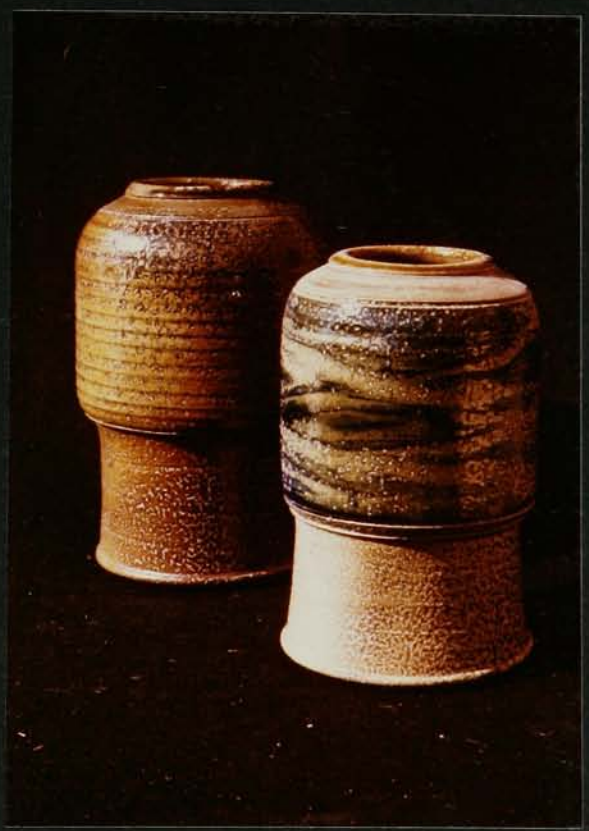


Figure 21. Pair of vases.

Figure 22. Vase.

Figure 23. Vase.

CONCLUSION

This paper is an accumulation of data gathered and observations made during my thesis work at R.I.T. My intent, throughout the research, was not to develop strict controls or rules pertaining to salt glazing; I feel that, considering the nature of the process, this would be unwise if not impossible. The character of the salt kiln is, at times, so strong that it seems to have a will of its own, dripping glaze from the top of its arch onto pots, reducing in certain areas, oxidizing in others, darkening pieces that were intended to be light, and in general, producing results that are often quite different from those previsualized. Moreover, my objective was to acquire an understanding of the many techniques and variables found in the salt glazing process, thereby, if nothing else, increasing the odds of my using the medium successfully.

I feel that I have accomplished this goal.

APPENDIX A

Fire Bricks Listed in Order of Ability to Resist Salt Glazing*

Rating	Brick Identification	% SiO_2	% Al_2O_3
Excellent	Spartan		85
Excellent	Alusite-D	23.9	71.3
Good	Walsh XX	53	41
Good	Woodland X	56.8	37.0
Poor	Crescent		
Poor	King		
Poor	Keystone		
Poor	Temple		

* The alumina and silica contents are given where available.

APPENDIX B

TEST SERIES WITH ADDITIONS OF FLINT

E.P.K.	Flint	% Absorb.	Al_2O_3/SiO_2
100	---	7.3	1:2.0
"	5	9.5	1:2.2
"	10	10.3	1:2.4
"	15	10.9	1:2.7
"	20	11.6	1:2.9
"	25	11.8	1:3.1
"	35	13.9	1:3.3
"	50	14.2	1:4.0
"	90	16.0	1:5.9
"	200	16.6	1:11.0

A.P.G.	Flint	% Absorb.	Al_2O_3/SiO_2
100	---	3.1	1:2.5
"	5	4.9	1:2.7
"	10	6.2	1:3.0
"	15	6.8	1:3.2
"	20	7.5	1:3.4
"	25	8.4	1:3.6
"	35	9.8	1:4.1

Test Body	Flint	% Absorb.	Al_2O_3/SiO_2
100	---	5.4	1:3.0
"	3	5.8	1:3.2
"	6	6.2	1:3.4
"	9	6.7	1:3.6
"	12	7.2	1:3.7
"	15	7.6	1:3.9

APPENDIX B, cont.

TEST SERIES WITH ADDITIONS OF FELDSPAR

E.P.K.	Custer Feldspar	% Absorb.
100	--	7.3
"	5	7.0
"	10	4.9
"	15	3.0
"	25	1.6
"	35	2.5

A.P.G.	Custer Feldspar	% Absorb.
100	--	3.1
"	5	2.3
"	10	1.1
"	20	0.6
"	30	0.0
"	40	0.0

Test Body	Custer Feldspar	% Absorb.
100	--	5.4
"	3	2.9
"	6	2.7
"	9	2.4
"	12	1.4
"	15	0.9

APPENDIX B, cont.

TEST BODY WITH COMBINED ADDITIONS OF FLINT AND FELDSPAR

Test Body	Flint/ Feldspar	% Absorb.	Al_2O_3/SiO_2*
100	---	5.4	1:3.0
"	2 / 2	5.1	1:3.2
"	4 / 4	4.3	1:3.3
"	6 / 6	3.5	1:3.4
"	8 / 8	2.7	1:3.5
"	10 / 10	2.5	1:3.6
"	12 / 12	2.5	1:3.7

*The Al_2O_3/SiO_2's given are exclusive of the additions of feldspar which contains little free silica.

APPENDIX B,cont.

TEST SERIES WITH ADDITIONS OF PLASTIC VITROX

E.P.K.	Plastic Vitrox	% Absorb.
100	--	7.3
"	5	8.9
"	10	8.3
"	15	8.2
"	20	8.1
"	25	7.0
"	30	6.7
"	35	5.4

A.P.G.	Plastic Vitrox	% Absorb.
100	--	3.1
"	5	4.0
"	10	4.6
"	15	5.0
"	20	3.6
"	25	3.3
"	30	3.2
"	35	3.2

Test Body	Plastic Vitrox	% Absorb.
100	--	5.4
"	3	5.0
"	6	4.2
"	9	3.7
"	12	3.7
"	15	2.7

APPENDIX C

Salt Slip

(For application on wet, dry or bisqued ware.)

XX Sagger	25
Tenn. #5 Ball	25
Buckingham feldspar	25
Flint	25
	100

Rust Brown	Red iron oxide	4%
Orange	Uranium oxide	10%
Straw tan	Rutile	10%
Green	Rutile	6%
	Cobalt oxide	2%
Blue	Cobalt oxide	2%
Black	Chromium oxide	2%
	Cobalt oxide	2%
	Red iron oxide	3%
	Manganese dioxide	3%
Iridescent-Green	Titanium dioxide	10%
	Cobalt oxide	1%
Iridescent-Rust	Titanium dioxide	10%
	Red iron oxide	4%

APPENDIX C, cont.

Rhodes Black Glaze
(midnight blue to black)

Albany	85
Nepheline Syenite	15
	100

Cobalt oxide	5%
Manganese dioxide	1%

Voulkos Plum
(yellow to rich red-brown)

Buckingham feldspar	42.0
Whiting	15.8
Zinc oxide	2.1
Kaolin	9.8
Flint	21.1
Red iron oxide	9.2
	100.0

APPENDIX C, cont.

Q 10 Satin

(opaque-white, good liner)

Bainbridge feldspar	40
Dolomite	20
Kaolin	20
Flint	20
	100

APPENDIX C, cont.

Salt Body #1	
C.H. Goldart	50
Jordan	25
A.P.G.	25
Feldspar	5
Grog	5
	110

Salt Body #2	
C.H. Goldart	50
Tenn. #5 Ball	25
A.P.G.	25
Flint	5
Feldspar	5
Grog	5
	110

Val Cushing Body	
C.H. Goldart	25
E.P.K.	15
A.P.G.	15
Tenn. #5 Ball	25
Flint	10
Feldspar	10
	100

Alfred School Body	
Jordan	50
Tenn. #5 Ball	25
A.P.G.	15
Flint	5
Feldspar	5
	100

Porcelain #1	
E.P.K.	25
Tenn. #5 Ball	25
Flint	25
Feldspar	25
	100

Porcelain #2	
E.P.K.	25
Tenn. #5 Ball	25
XX Sagger	25
Flint	12.5
Feldspar	12.5
	100.0

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